GeoTerrace-2026-029

The Influence of Land Cover Type and Seasonal Vegetation on Effective Ground Point Density in Airborne Laser Scanning (Using the Example of LiAir V70)

***Y. Vash, M. Nychvyd, I. Kalynych, N. Kablak** *(Uzhhorod National University),* **N. Vash** *(Uzhhorod Scientific Lyceum)*

SUMMARY

The paper investigates the spatial and seasonal variability of the effective density of ground points obtained from LiAir V70 airborne laser scanning data for different land cover types. Field data were generated based on three survey cycles performed in March, April, and June, which allowed assessing the change in density under different phenological conditions. A comparative analysis of the actual density of ground points for the main land cover types (roads, forests, gardens, hayfields, shrubs) during three survey campaigns. The spatial heterogeneity of the density and its seasonal changes between the spring and summer periods were assessed. It was found that the effective density of ground points significantly depends on the type of land cover and the phenological state of vegetation. The highest and most stable values are characteristic of anthropogenic surfaces (roads), while for natural surfaces, in particular forests, a significant decrease in density is observed in the summer period. The results obtained confirm the significant influence of vegetation and seasonal dynamics on the effective density of ground points, which must be taken into account when interpreting airborne laser scanning data and assessing the quality of digital terrain models.

Keywords: Airborne laser scanning; LiDAR; Point cloud density; Ground points; Land cover; Seasonal variability; Vegetation phenology; LiAir V70.

Corresponding Author: yaroslav.vash@uzhnu.edu.ua

Introduction

The quality of a digital terrain model directly depends on the characteristics of the input point cloud, in particular its density, spatial distribution and efficiency of ground point classification (Karel & Kraus, 2006; Butenko et al., 2024). The use of high-density point clouds ensures the creation of highly accurate three-dimensional terrain models and is successfully used to solve engineering and geodetic problems (Savchyn et al., 2025). At the same time, modern research is focused on the practical application of laser scanning data to solve individual applied problems, in particular, assessing the state of green spaces (Vash & Gubar, 2023). However, the issue of the influence of the type of land cover and seasonal changes in vegetation on the effective density of Ground points after their classification has not been sufficiently studied.

Regulatory documents regulating the performance of airborne laser scanning determine the minimum required design (nominal) density of the point cloud, however, such requirements are mostly based on generalized characteristics of the territory and do not take into account the influence of physical and geographical conditions, land cover type and phenological state of vegetation on the actual density of Ground class points after classification (Kalynych et al., 2025).

In this regard, it is relevant to study the patterns of changes in the effective density of ground points depending on the type of land cover and seasonal conditions, which will allow to substantiate the requirements for the parameters of airborne laser scanning and increase the reliability of building digital terrain models.

The aim of the work is to study the influence of the type of land cover, physical and geographical features of the territory and seasonal dynamics of vegetation on the effective density of Ground class points obtained from the results of airborne laser scanning using the LiAir V70 system.

Method and Theory

According to current regulatory requirements (Ministry of Agrarian Policy, 2025), the optimal period for airborne laser scanning is the pre-vegetation period, the beginning of the vegetation period or the post-vegetation period of plants. When airborne laser scanning is carried out during the growing season, the calculated (nominal) point cloud density should be increased to ensure the required effective density of classified ground points, taking into account the characteristics of the relief and the type of land cover.

The design (nominal) density of point clouds, according to (Ministry of Agrarian Policy, 2025; Shan & Toth, 2018), is estimated using the following equation:

$$\boldsymbol{E} = \frac{\boldsymbol{N}}{\boldsymbol{V} \times \boldsymbol{H} \times 2 \times \boldsymbol{tan}\frac{\boldsymbol{\alpha}}{2}} \tag{1}$$

where N is the laser pulse repetition frequency (Hz);
E is the design (nominal) point cloud density (points/m²);
V is the aircraft flight speed (m/s);
α is the scanner field of view (°);
H is the flight altitude above ground level (m).

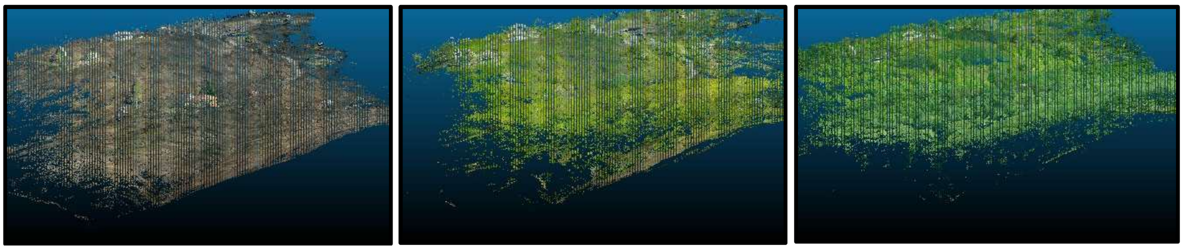
Other methods for estimating point cloud density are presented in Babushka & Burshtynska (2019). The suburban monitoring station of Uzhhorod National University, "Derenivka," located near the village of Nyzhnie Solotvyno, 15 km from Uzhhorod, was chosen as the experimental site. The choice of the experimental site was based on the possibility of conducting regular flights after obtaining the appropriate permits and the absence of restrictions on airspace use, which allowed for multiple surveys to be conducted under identical conditions. According to cadastral and topographic data, the study area is characterized by steep southern slopes, a partially built-up lower part, the presence of a road network, vineyards, shrubs, and forest vegetation, which creates diverse conditions for assessing the impact of land cover types on ALS results (Vash et al, 2025).

Three airborne laser scanning campaigns were conducted as part of the study in March, April, and June 2026. To ensure that differences in ground point density were primarily due to seasonal and land cover conditions, all campaigns were conducted using identical flight parameters. The main flight characteristics are presented in Table 1. Flight positioning was provided in RTK mode using corrections from the ZakPOS active permanent GNSS network (ZAKPOS, 2026). This ensured highly accurate flight path determination and comparability of results across all three survey cycles.

Table 1. *Design flight parameters and actual point cloud density during airborne laser scanning using LiAir V70 in the territory of the Derenivka research area*

Project name	***Speed, m/s***	***Height, m***	***Design density, points/m²***	***Actual density, points/m²***
2026-06-17	*15*	*120*	*47*	*29.22*
2026-04-07	*15*	*120*	*47*	*25.81*
2026-03-09	*15*	*120*	*47*	*24.57*

The visualization of the point clouds obtained during the three survey campaigns, shown in Figure 1, clearly shows the impact of vegetation on the results of airborne laser scanning.

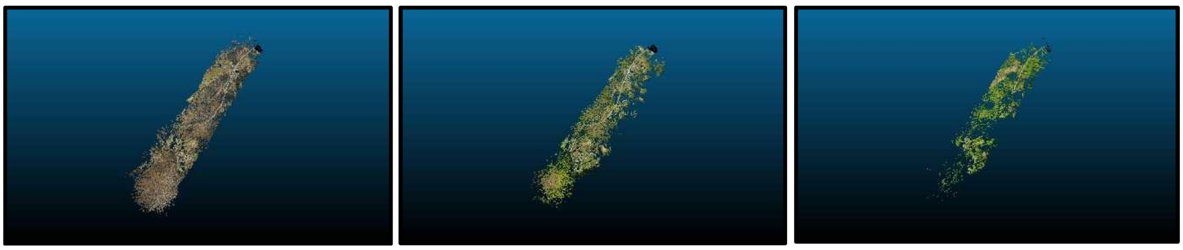


a) b) c)

Figure 1. *Seasonal variations in point cloud density obtained from airborne laser scanning data:*
(a) March; (b) April; (c) June

Results

Classification of laser point clouds was performed in the TerraSolid software environment (Terrasolid, 2025) using the TerraScan UAV, TerraMatch UAV, and TerraModeler UAV modules. The processing procedure included automated classification with subsequent manual verification and correction of its results. After classification was completed, the data were exported in .las format in accordance with the requirements (Ministry of Agrarian Policy, 2025). As a result, a set of “Ground”-class points was formed.



a) b) c)

Figure 2. *Seasonal variation in Ground-class point density obtained from airborne laser scanning data:*
(a) March; (b) April; (c) June

To analyze their effective density within individual land cover types (roads, forests, gardens, hayfields and shrubs), study polygons were created. For each polygon, its area, the number of Ground-class points and their density (points/m²) were automatically calculated using TerraScan. The obtained values were used for further comparative analysis between different land cover types and seasons of observations (Figure 2). The obtained effective density of Ground-class points for each land cover type is presented in Table 2.

Table 2. *Seasonal variations in the effective density of Ground-class points*

Land cover type	***Ground-class point density, points/m²***		
	09.Mar	***07.Apr***	***17.Jun***
Roads	*0,74*	*0,66*	*0,71*
Forests	*3,80*	*1,65*	*0,64*
Orchards	*1,70*	*1,74*	*1,47*
Hayfields	*1,18*	*0,90*	*0,88*
Shrubs	*1,65*	*1,80*	*1,57*
Average	*2,43*	*2,07*	*1,54*

The effective density of points of the "Ground"-class for individual land cover types is shown in Figure 3. The analysis of the obtained results shows that, despite the general decrease in the density of points in the summer period, its greatest decrease is observed in areas covered with deciduous forest. This confirms the significant influence of dense woody vegetation on the penetration of laser pulses to the earth's surface and, accordingly, on the effective density of points of the "Ground" class.

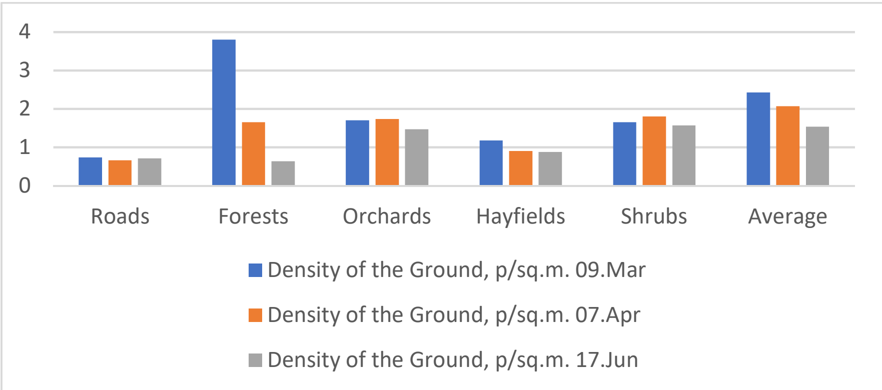


Figure 3. *Spatial and seasonal variability of the effective density of points of the "Ground"- class for different land cover types according to the results of multi-temporal airborne laser scanning*

Conclusions

The study investigates the influence of land cover type and seasonal vegetation state on the effective density of Ground-class points obtained from airborne laser scanning. Analysis of three survey campaigns conducted in March, April, and June showed that the actual effective density of Ground class points significantly differs from the design (nominal) density of the point cloud and depends on the land cover type and phenological state of vegetation. The greatest density losses after classification are observed in areas covered by deciduous forest.

The obtained results confirm the pronounced spatial and seasonal variability of the effective density of Ground class points. The highest values were obtained for anthropogenic surfaces, in particular roads, while natural land cover types are characterized by much greater variability. As vegetation developed during the growing season, the effective density of points of the "Ground" class decreases noticeably, which must be taken into account when planning the parameters of airborne laser scanning and selecting the design density of the point cloud to ensure the required quality of digital terrain models.

References

Babushka, A. V., & Burshtynska, Kh. V. (2019). Aviation laser scanning: Textbook. Lviv: Lviv Polytechnic Publishing House.

Butenko, Y., Kutsenko, O., Tertyshna, O., Tkachuk, Y., & Yaretska, K. (2024). Formuvannia shchilnoi khmary tochok ta yii opratsiuvannia pry stvorenni tsyfrovoi modeli reliefu [Formation of a dense point cloud and its processing for creating a digital terrain model]. *Zemleustrii, kadastr i monitorynh zemel, 3*, 109–122. https://doi.org/10.31548/zemleustriy2024.03.09

Kalynych, I., Vash, Y., & Nychvyd, M. (2026). Methodological principles for determining the minimum required density of the point cloud of aviation laser scanning considering regulatory requirements for accuracy and physical and geographical conditions of the territory. Ukrainian *Journal of Applied Economics and Technology, 1*, 311–315. https://doi.org/10.36887/2415-8453-2026-1-58

Karel, W., & Kraus, K. (2006). Quality parameters of digital terrain models. In J. Höhle (Ed.), The EuroSDR test: Checking and improving of digital terrain models (*EuroSDR Official Publication No. 51*, pp. 125–139). European Spatial Data Research (EuroSDR). https://www.eurosdr.net/sites/default/files/uploaded_files/eurosdr_publication_ndeg_51.pdf

LiDAR Solutions. (2022). LiAir V70 user manual. Retrieved August 18, 2025, URL https://www.lidarsolutions.com.au/wp-content/uploads/2022/01/LIAIR-V70-User-Manual.pdf

Ministry of Agrarian Policy and Food of Ukraine. (2025, April 17). Order of the Ministry of Agrarian Policy and Food of Ukraine No. 868 “On approval of the procedure for topographic surveying at scales 1:5000, 1:2000, 1:1000, and 1:500”. Retrieved August 18, 2025, URL https://zakon.rada.gov.ua/laws/show/z0868-25#n1416

Savchyn, I., Lozynskyi, V., Romanyshyn, O., & Malanchuk, M. (2025). Geodetic monitoring of roof deformations in repurposed structures: A case study from Rivne, Ukraine. In Proceedings of the International Conference of Young Professionals GeoTerrace-2025. European Association of Geoscientists & Engineers. https://doi.org/10.3997/2214-4609.202552020

Shan, J., & Toth, C. K. (Eds.). (2018). Topographic laser ranging and scanning: principles and processing. CRC press.

Terrasolid. (2025) TerraScan user guide. Retrieved August 18, 2025, URL https://www.terrasolid.com/guides/tscan/introterrascansettings.html

Vash, Y. & Hubar, Yu. (2023) Formation of 3D Models of Tree Trunks in the T. Masarik Square in Uzhhorod Built Using the Materials of TLS, Terrestrial Photogrammetry and Their Combination. In International Conference of Young Professionals «GeoTerrace-2023» (Vol. 2022, No. 1, pp. 1–5). European Association of Geoscientists & Engineers. https://doi.org/10.3997/2214-4609.2023510039

Vash, Y., Nychvyd, M., Kalynych, I., & Kablak, N. (2025, October). The Influence of Surface Type on the Accuracy of Digital Terrain Models Derived from Airborne Laser Scanning Data (Using LiAir V70 as a Case Study). In International Conference of Young Professionals «GeoTerrace-2025» (Vol. 2025, No. 1, pp. 1-5). European Association of Geoscientists & Engineers. https://doi.org/10.3997/2214-4609.202552041

ZAKPOS. (n.d.). ZAKPOS permanent GNSS network. https://ua-pos.net/